2-2010

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William Ebben
*Marquette University*, william.ebben@marquette.edu

McKenzie Fauth
*Marquette University*

Erich Petushek
*Marquette University*

Luke Garceau
*Marquette University*, luke.garceau@marquette.edu

Brittni Hsu
*Marquette University*

*See next page for additional authors*

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William P. Ebben

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

McKenzie L. Fauth

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

Erich J. Petushek

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

Luke R. Garceau

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*

*Journal of Strength and Conditioning Research*, Vol. 24, No. 2 (February 2010): pg. 408-415. DOI. 

*Milwaukee, WI*

Brittni E. Hsu

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

Brittney N. Lutsch

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

Christina R. Feldmann

*Program in Exercise Science, Strength and Conditioning Research Laboratory, Department of Physical Therapy, Marquette University*
*Milwaukee, WI*

**Abstract**

This study evaluated gender differences in the magnitude and timing of hamstring and quadriceps activation during activities that are believed to cause anterior cruciate ligament (ACL) injuries. Twelve men (age = 21.0 ± 1.2 years; body mass = 81.61 ± 13.3 kg; and jump height = 57.61 ± 10.15 cm) and 12 women (age = 19.91 ± 0.9 years; body mass = 64.36 ± 6.14 kg; and jump height = 43.28 ± 7.5 cm) performed 3 repetitions each of the drop jump (jump) normalized to the subject's vertical jump height, and a sprint and cut at a 45-degree angle (cut). Electromyography (EMG) was used to quantify rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), lateral hamstring (LH) and medial hamstrings (MH) activation, timing, activation ratios, and timing ratios before and after foot contact for the jump and cut and normalized to each subject's hamstring and quadriceps maximum voluntary isometric contraction. Data were analyzed using an analysis of variance with results demonstrating that during the postcontact phase of the cut, men demonstrated greater LH and MH activation than women. In the precontact phase of the jump, men showed earlier activation of the VL and VM, than women. Women produced longer RF and VM muscle bursts during the postcontact phase of the cut. Additionally, men showed a trend toward higher hamstring to quadriceps activation ratio than women for the postcontact phase of the cut. This study provides evidence that men are LH dominant during the postcontact phase of the cut compared with women, whereas women sustain RF activation longer than men during this phase. Men activate quadriceps muscles earlier than women in the precontact phase of the jump. Training interventions may offer the potential for increasing the rate and magnitude of hamstring muscle activation. These outcomes should be evaluated using EMG during movements that are similar to those that cause ACL injuries to determine if gender differences in muscle activation can be reduced.

**Key Words:** sex differences, anterior cruciate ligament, injury prevention, cocontraction

# Introduction

Anterior cruciate ligament (ACL) injuries disproportionately affect female athletes, accounting for 69.0% of serious knee injuries (12) and 4.8% of all athletic injuries (11,19). The hamstrings and quadriceps relationship to the ACL has been described. The hamstrings function as an ACL synergist by decreasing the anterior translation of the tibia and reducing interior tibial rotation during a simulated squat (16). Hamstring activation also stabilizes the ACL-deficient knee, aids ligaments in maintaining joint stability, equalizes articular surface pressure distribution (15), and regulates the joints' mechanical impedance (1,24). The quadriceps causes significant anterior displacement of the tibia, resulting in gross ACL injury when strong quadriceps forces are simulated (7). During cadaveric assessment of jump landings, the ACL instrumented with a load cell produced strain proportional to the increase in quadriceps forces during these landings (25). Thus, the hamstrings and quadriceps are ACL synergists and antagonists, respectively. Previous research has assessed the activation of the hamstring and quadriceps muscles during a variety of movements believed to simulate those that cause ACL injuries (functional movements) (2,4-6,10,14,15,17,18,20-23,27).

Studies have examined hamstring and quadriceps muscle activation during functional movements of women (5) or men (2,18) only, whereas others compared gender differences during a variety of functional movements (4,6,10,14,15,17,20-23,27). A number of these studies evaluated the muscle activation in response to jump landings using the same drop jump height for men and women (5,10,17,21,27), potentially creating disproportionate task intensity for women, who do not jump as high as men (9). Results from other studies examining gender differences in hamstring and quadriceps activation and timing during functional movements are mixed. Studies failed to find gender differences in hamstring and quadriceps muscle activation (10), hamstring activation (17,20,23,27), hamstring and quadriceps activation timing (21), or quadriceps activation timing (6). In contrast, some evidence of gender differences has been established.

Women have been shown to activate the quadriceps more than men during functional movements (4,14,15,17,20,23,27) and have demonstrated lower hamstring to quadriceps activation ratios (17,20). Greater hamstring activation by women compared with men has been demonstrated before foot contact (4), with greater lateral hamstring (LH) activation after foot contact (21) or with greater medial hamstring (MH) activation during jump landings (22). In contrast, some evidence suggests that women, compared with men, have less hamstring activation during cutting (15) and running (14).

In addition to gender differences in the magnitude of activation, differences in the timing of hamstring and quadriceps activation have not been demonstrated in some studies (4,21), whereas others have found differences with men producing delayed semimembranosus onset at foot contact, compared with women, which was thought to be a protective mechanism allowing maximum hamstring activation to correspond with the timing of anterior tibial shear (6,26).

At present, the research regarding gender differences in the timing and magnitude of hamstring and quadriceps activation during functional movements is equivocal. No study examining the timing and magnitude of drop jump landings has normalized jump height to individual ability. Previous research describing gender difference in hamstring to quadriceps activation ratios or timing ratios is limited. Therefore, the purpose of this study was to assess the magnitude and timing of hamstring and quadriceps activation, hamstring to quadriceps activation ratios, and hamstring to quadriceps timing ratios of a variety of hamstring and quadriceps muscles before and after foot contact during drop jumps and 45-degree-angle cuts for the purpose of assessing gender differences in these variables.

## Methods

### *Experimental Approach to the Problem*

This study evaluated the hypothesis that there are gender difference in the timing and magnitude of hamstring and quadriceps muscle activation, as well as activation and timing ratios during a drop jump landing (jump) and a 45-degreeangle cut (cut). Independent variables included the pre- and post-foot contact phase for both the jump and cut and gender. Dependent variables included the root mean square (RMS) electromyography (EMG) representing the magnitude of muscle activation and timing of muscle burst of the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM) LH, and MH, expressed as a percentage of maximal voluntary isometric contraction (MVIC), as well as averaged measures of hamstrings and quadriceps muscles expressed as activation and timing ratios.

## *Subjects*

Subjects included 12 men (age = 21.0 ± 1.2 years; body mass = 81.61 ± 13.3 kg; and jump height 57.61 ± 10.15 cm) and 12 women (age = 19.91 ± 0.9 years; body mass = 64.36 ± 6.14 kg; and jump height 43.28 ± 7.5 cm) university students. Inclusion criteria included subjects who are 18-27 years old, who participated in high-school or college sports, who were without orthopedic lower limb or known cardiovascular pathology, and who had no contraindications to resistance, sprint, agility, or plyometric training.

The vertical jumping ability of women in this study was 75.2% of the value of the men. All subjects currently participated in collegiate athletics, club sports, or intramurals, with 2 women and 1 man participating in varsity intercollegiate athletics. Ten of the men and 6 of the women currently participated in resistance training an average of twice per week. All subjects participated in high-school sports as well. Women subjects participated in an average of 2.33 sports in high school including 7 who ran track, 4 each who played soccer and basketball, 3 each who participated in volleyball and cross country, 2 who were involved in swimming and softball, and 1 each who participated in tennis, crew, and figure skating. Men subjects participated in an average of 2.08 high-school sports including 5 each who played football and baseball, 4 who played basketball, 3 who ran track, 2 each who played tennis and golf, and 1 each who participated in wrestling, swimming, soccer, and cross country. All subjects provided informed consent, and the study was approved by the university review board.

## *Procedures*

All subjects were familiarized with the test procedures during the pretest orientation session. Subjects performed a general warm-up including 5 minutes on an ergometer and a dynamic warm-up for each of the major muscle groups to be used in the test exercises. The subjects practice performing MVICs at 60 degrees of knee flexion for the hamstrings and quadriceps muscle groups, with seated leg curl and leg extension machines, respectively, loaded with an immovable mass. Subjects' vertical jump heights were tested using a Vertec (Sports Imports, Columbus, OH, USA). The vertical jump height information was then used to individualize the height of the warm-up and test jump. Subjects also practice the cut, which included an 8-m sprint of maximal volitional velocity that transitioned into a 45-degree-angle cut. The jump and cut were chosen for analysis because jump landings and cutting have been implicated in noncontact ACL injuries (3).

After approximately 72 hours, subjects returned for the resting session. Each subject performed 3 trials of the MVICs for the hamstrings and quadriceps with order randomized between subjects and alternated with 1 minute of rest between each MVIC. Subjects then practice 3 repetitions each of the test jump and cut, followed by 3-minute rests. Subjects then performed the test exercises including 3 repetitions each of the jump and cut, in a randomized order, with 1 minute of rest between each repetition.

## *Instrumentation*

Electromyography was used to quantify muscle activity using an 8 channel telemetered EMG system (Myomonitor IV; DelSys Inc., Boston, MA, USA). The input impedance was 1015 Ohms with a common-mode rejection ratio of > 80 dB. Electromyographic data from the RF, VM, VL, LH, and MH muscles were recorded at 1,024 Hz using rectangular-shaped (19.8 mm wide and 35 mm long) bipolar surface electrodes with 1 x 10 mm 99.9% Ag conductors and an interconductor distance of 10 mm. Electrodes were placed on the longitudinal axis of the muscles. The RF electrode was placed halfway between the greater trochanter and medial epicondyle of the femur. The VL electrode was placed on-quarter of the distance from the lateral line of the knee joint to the anterior superior iliac spine. The VM electrode was placed on-fifth of the distance from the medial joint line to the anterior superior iliac spine. The LH electrode was placed halfway between the ischial tuberosity and the fibular insertion site, at least 5 cm proximal to the musculotendinous junction. The MH electrode was placed halfway between the ischial tuberosity and the tibial insertion point, at least 4 cm proximal to the musculotendinous junction. A common reference electrode was placed 10 mm anterior and halfway between the medial condyle and media malleolus of the tibia. Skin preparation included shaving hair if necessary, abrasion, and cleaning the surface with alcohol. Elastic tape was applied to ensure electrode placement to minimize motion artifact and to provide strain relief for the electrode cables. Surface electrodes were connected to an amplifier and streamed continuously through an analog to digital converter (DelSys Inc.) to an IBM-compatible notebook computer. The timing of the foot contact for the jump and cut was synchronized with the EMG system using a switch mat (Model CVP 1723; Lafayette Industries, Lafayette, IN, USA).

## *Data Reduction*

All data were filtered with a 10-450 Hz band pass filter, saved, and analyzed with the use of software (EMGworks 3.1; DelSys Inc.). Root mean square signal processing was used, and data were calculated using a 125-milliseconds (ms) moving window. Data were analyzed for seconds 2-3 of the MVICs, using the highest of the 3 trials. Data were analyzed to identify the pre- and postcontact muscle burst timing and the magnitude of activation for the jump and cut. Burst onset and offset were determined as the points at which the RMS EMG values exceeded 150 percent of baseline before, and fell below 150 percent of baseline after, foot contact. The 3 trial RMS EM G values for the muscles assessed during the jump and cut were averaged and normalized to the RMS EMG of their respective MVIC. Hamstring to quadriceps activation and timing ratios were calculated by taking the collective average of the LH and MH and dividing by the collective average of the RF, VL, and VM to provide a global assessment of the functioning of these muscle groups and their ratios.

## *Statistical Analyses*

Data were evaluated with SPSS 16.0 using an analysis of variance to assess gender differences in the magnitude and timing of hamstring and quadriceps activation, hamstring to quadriceps activation ratios, and hamstring to quadriceps timing ratios of a variety of hamstring and quadriceps muscles before and after foot contact during jump and cut. Data are presented as mean ± *SD*.

 

# Results

## *Magnitude of Activation*

No gender differences in the magnitude of muscle activation during the precontact phase of the jump were found. During the postcontact phase of the jump, men demonstrated greater LH activation ($p$ = 0.04) compared with women. No other gender differences in muscle activation were found. In the precontact phase of the cut, no gender-based differences in muscle activation were found for any of the muscles assessed. However, during the postcontact phase of the cut, men demonstrated greater LH ($p$ = 0.028) and MH ($p$ = 0.049) activation than women. Table 1 shows all of the results of the analysis of muscle activation during the pre- and postcontact phases of the jump and cut.

## *Timing of Activation*

Statistical analysis reveals that in the precontact phase of the jump, men showed earlier activation of the VL (p= 0.012) and VM (p = 0.016) than women. No significant differences were found for the other muscles assessed during the precontact phase of the jump. Additionally, no significant differences were found for any of the muscles assessed in the postcontact phase of the jump. Analysis of gender differences in the timing of muscle activation during the precontact phase of the cut revealed no significant gender differences, although women demonstrated a longer duration of RF ($p$ = 0.009) and VM ($p$ = 0.015) muscle burst during the postcontact phase of the cut. Table 2 shows all of the results of the analysis of the timing of muscle activation during the pre- and postcontact phases of the jump and cut.

## *Activation Ratios*

When the activation of the LH and MH are averaged and expressed in a ratio with the aggregate average of the RF, VL, and VM, men demonstrated a trend toward a higher hamstring activation ratio than women for the postcontact phase of the cut (p = 0.064). No other significant differences in this measure were found for the pre- and postjump condition and for the precut condition as well. Table 3 shows all of the results of the analysis of the hamstring to quadriceps activation ratios during the pre- and postcontact phases of the jump and cut.

 

## *Timing Ratios*

In the analysis of the timing in the hamstring and quadriceps groups, the average LH and MH were expressed in a ratio with the aggregate average of the RF, VL, and VM, with women demonstrating earlier activation of the hamstring in the precontact phase of the cut ($p = 0.04$). No other significant differences in this measure were found for postcontact condition of the cut or for the pre- and postcontact condition of the jump. Table 4 shows all of the results of the analysis of the hamstring to quadriceps timing ratios during the pre- and postcontact phases of the jump and cut.

**Table 1.** Muscle activation (% of MVIC) during the pre- and postcontact phases of the jump and cut.

| | | Men | | Women | | |
|---|---|---|---|---|---|---|
| | Muscle | Mean ± *SD* | Range | Mean ± *SD* | Range | *p* value |
| Jump (precontact) | RF | 26.07 ± 21.92 | 7.43–71.11 | 19.74 ± 7.40 | 10.63–36.61 | 0.35 |
| | VL | 30.49 ± 13.20 | 9.47–51.10 | 24.97 ± 16.43 | 3.78–56.37 | 0.38 |
| | VM | 40.07 ± 30.64 | 18.66–126.97 | 37.99 ± 30.26 | 2.14–101.00 | 0.87 |
| | LH | 26.24 ± 21.40 | 2.15–63.91 | 16.68 ± 13.10 | 4.46–51.24 | 0.22 |
| | MH | 39.51 ± 45.93 | 1.75–167.80 | 36.32 ± 47.30 | 1.07–150.21 | 0.87 |
| Jump (postcontact) | RF | 64.71 ± 46.32 | 18.52–167.00 | 49.81 ± 21.46 | 19.75–90.70 | 0.34 |
| | VL | 97.61 ± 61.17 | 35.52–256.68 | 89.73 ± 51.47 | 46.51–228.23 | 0.75 |
| | VM | 80.50 ± 39.56 | 28.80–185.68 | 85.09 ± 36.94 | 30.75–152.47 | 0.77 |
| | LH | 41.23 ± 43.32 | 2.54–155.50 | 16.67 ± 16.11 | 3.65–57.30 | 0.04* |
| | MH | 27.24 ± 27.12 | 1.50–80.59 | 23.71 ± 27.94 | 4.65–91.02 | 0.77 |
| Cut (precontact) | RF | 51.39 ± 41.58 | 14.08–170.84 | 42.24 ± 37.12 | 11.16–145.90 | 0.58 |
| | VL | 118.33 ± 73.36 | 29.52–321.76 | 113.98 ± 87.61 | 48.29–378.30 | 0.90 |
| | VM | 100.27 ± 34.21 | 47.22–140.87 | 99.53 ± 35.53 | 51.02–163.73 | 0.96 |
| | LH | 122.78 ± 73.41 | 16.92–232.87 | 102.63 ± 61.59 | 40.79–283.19 | 0.47 |
| | MH | 106.99 ± 38.94 | 60.90–200.00 | 96.95 ± 68.48 | 29.86–286.63 | 0.66 |
| Cut (postcontact) | RF | 85.61 ± 55.45 | 20.35–208.69 | 86.42 ± 57.00 | 34.06–208.22 | 0.90 |
| | VL | 199.40 ± 108.17 | 56.19–440.94 | 127.43 ± 65.21 | 59.80–295.23 | 0.06 |
| | VM | 144.11 ± 66.64 | 71.98–277.53 | 128.36 ± 59.46 | 58.15–273.78 | 0.57 |
| | LH | 90.10 ± 53.00 | 25.69–197.79 | 50.79 ± 16.24 | 30.90–78.75 | 0.03* |
| | MH | 63.38 ± 31.80 | 22.80–127.80 | 37.75 ± 40.59 | 10.03–154.38 | 0.05* |

*Statistically significant difference between men and women.
MVIC = maximal voluntary isometric contraction; RF = rectus femoris; VL = vastus lateralis; VM = vastus medialis; LH = lateral hamstring; MH = medial hamstring.

 

**Table 2.** Timing of muscle activation (milliseconds) during the jump and cut.

| | | Men | | Women | | |
|---|---|---|---|---|---|---|
| | Muscle | Mean ± *SD* | Range | Mean ± *SD* | Range | *p* value |
| Jump (precontact) | RF | 69.44 ± 35.19 | 41.33–165.00 | 57.67 ± 8.09 | 45.67–72.00 | 0.27 |
| | VL | 62.08 ± 16.28 | 39.00–82.67 | 46.95 ± 10.10 | 28.33–65.33 | 0.012* |
| | VM | 64.08 ± 12.20 | 50.00–95.33 | 52.39 ± 9.77 | 35.00–73.67 | 0.016* |
| | LH | 79.97 ± 23.91 | 35.33–110.67 | 81.47 ± 18.95 | 52.33–108.33 | 0.87 |
| | MH | 103.56 ± 96.22 | 43.33–404.00 | 80.72 ± 22.19 | 50.33–130.00 | 0.43 |
| Jump (postcontact) | RF | 224.17 ± 41.63 | 150.00–289.00 | 236.97 ± 23.13 | 196.00–291.00 | 0.36 |
| | VL | 225.70 ± 37.28 | 169.67–278.67 | 236.08 ± 29.69 | 174.30–270.00 | 0.46 |
| | VM | 223.36 ± 30.68 | 180.33–280.33 | 236.80 ± 18.14 | 215.00–267.33 | 0.21 |
| | LH | 204.09 ± 39.94 | 147.67–260.67 | 216.14 ± 29.32 | 152.30–265.00 | 0.45 |
| | MH | 208.89 ± 68.15 | 121.67–398.00 | 209.94 ± 26.67 | 143.30–252.30 | 0.96 |
| Cut (precontact) | RF | 67.08 ± 20.86 | 41.67–114.67 | 60.89 ± 12.19 | 41.33–87.00 | 0.38 |
| | VL | 94.22 ± 36.07 | 48.00–182.33 | 81.89 ± 24.21 | 37.00–121.30 | 0.34 |
| | VM | 97.86 ± 29.83 | 67.33–161.67 | 82.97 ± 18.49 | 58.67–124.00 | 0.16 |
| | LH | 106.75 ± 43.37 | 37.00–207.00 | 107.89 ± 18.29 | 78.33–139.00 | 0.93 |
| | MH | 117.75 ± 21.17 | 80.33–158.00 | 119.78 ± 23.41 | 100.00–187.00 | 0.83 |
| Cut (postcontact) | RF | 166.47 ± 39.58 | 108.67–231.00 | 207.33 ± 29.21 | 136.67–254.30 | 0.009* |
| | VL | 150.86 ± 29.54 | 112.67–195.67 | 169.97 ± 31.89 | 124.00–219.00 | 0.14 |
| | VM | 155.17 ± 29.54 | 118.33–213.00 | 185.09 ± 22.69 | 141.33–211.00 | 0.015* |
| | LH | 171.61 ± 43.68 | 63.35–224.00 | 194.64 ± 26.53 | 136.67–230.00 | 0.14 |
| | MH | 179.77 ± 51.90 | 82.23–242.00 | 191.30 ± 38.94 | 119.30–263.00 | 0.54 |

*Statistically significant difference between men and women
RF = rectus femoris; VL = vastus lateralis; VM = vastus medialis; LH = later hamstring; MH = medial hamstring

**Table 3.** Hamstring to quadriceps activation ratios during the pre- and postcontact phases of the jump and cut.

| | Men | Women | |
|---|---|---|---|
| H:Q activation ratio | Mean ± *SD* | Mean ± *SD* | *p* value |
| Jump (precontact) | 1.01 ± 0.78 | 1.34 ± 1.62 | 0.54 |
| Jump (postcontact) | 0.55 ± 0.58 | 0.38 ± 0.57 | 0.48 |
| Cut (precontact) | 1.39 ± 0.42 | 1.36 ± 0.87 | 0.92* |
| Cut (postcontact) | 0.54 ± 0.17 | 0.41 ± 0.16 | 0.064 |

*Statistically significant difference between men and women.
H = hamstring; Q = quadriceps

**Table 4.** Hamstring to quadriceps timing ratios during the pre- and postcontact phases of the jump and cut.

| | Men | Women | |
|---|---|---|---|
| H:Q timing ratio | Mean ± *SD* | Mean ± *SD* | *p* value |
| Jump (precontact) | 1.49 ± 0.99 | 1.57 ± 0.36 | 0.787 |
| Jump (postcontact) | 0.93 ± 0.19 | 0.90 ± 0.11 | 0.643 |
| Cut (precontact) | 1.33 ± 0.25 | 1.54 ± 0.21 | 0.04* |
| Cut (postcontact) | 1.13 ± 0.27 | 1.04 ± 0.20 | 0.389 |

*Statistically significant difference between men and women.
H = hamstring; Q = quadriceps

# Discussion

This study demonstrates some gender differences in the magnitude and timing of hamstring and quadriceps muscle activation during functional movements that are similar to those that cause ACL injuries (3). These results contrast with previous research that found no gender differences in muscle activation (10) and with much of the previous literature on this topic.

 

Results of the present study demonstrate that during the precontact phase of jump landings and cutting, men and women are similar with respect to degree of activation of the hamstring and quadriceps muscles. This finding is consistent with those of Padua et al. (20) who assessed muscle activation during hooping. However, most studies have demonstrated gender differences in hamstring and quadriceps muscle activation before landing, including Zazulak et al. (27) who found that women demonstrated greater RF activation in the precontact phase, of single-leg drop landings. However, it should be noted that EMG activation of single-leg jumps has been shown to differ from bilateral jump (9) and are among the highest intensity jumping exercises (13). Thus, when subjects in this study used fixed drop jumps heights of 30.5 and 45.8 cm, this most likely represents a relative overload for the women compared with men because some evidence indicated that the jumping ability of women is 75.2% of the value of men (8). Thus, the women may have produced greater muscle activation as a result of the higher relative intensity of the exercise. This limitation is also present in other studies demonstrating that women had greater muscle activation before landing than men, when jumping from fixed heights, such as 25.4 and 30 cm benches that were not normalized to ability (17,21). Results of the present study are also in contrast to Chappel et al. (4) who demonstrated that women produced greater hamstring activation before stop-jump landings.

Previous research has shown that women have higher quadriceps activation than men during hopping (20), running (14), and cutting (14,15,23) with women and men producing 191% and 151% of their MVICs, respectively, during the postcontact period of a cutting maneuver (23). In the present study, no significant difference was found for quadriceps muscle activation, although the mean VL activation of women during the post-foot contact period was greater than the values of the men and approaching significance ($p = 0.081$).

The present study demonstrated that men produced greater LH activation during the postcontact period of the jump landing and supports these previous findings, in part. The increased LH activation of males in the present study was also demonstrated during the postcontact period of the cutting maneuver, enhancing the credibility of this finding of LH dominance of men. This degree of hamstring activation explains in part why men also demonstrated higher hamstring to quadriceps activation ratio during the post contact phase of the cutting maneuver, in the present study. These findings confirm those of Malinzak et al. (15) who showed that men produce more hamstring activation than women upon landing and during cutting and Landry et al. (14) who demonstrated that women had lower LH activation than men during running. Most research examining this issue has failed to find significant gender differences in hamstring activation upon landing during functional movements (4,10,20) or demonstrated that women had greater hamstring activation than men (21,22). Together, these findings suggest that rather than women being quadriceps dominant as previously proposed, men may be hamstring dominant, particularly with respect to the LH during landing.

In the present study, men showed earlier activation of the VL and VM than women during the pre-foot contact phase of the jump and women demonstrated a longer duration of RF muscle burst during the post-foot contact phase of the cut. Previous research examining the timing of muscle activation during functional movements has failed to demonstrate gender differences in any of the muscles studies (21) or for all but the semimembranosus, which was delayed before foot contact for men, which the authors reported to be a potential protective mechanism.

When the activation of the lateral and MH are averaged and expressed in a ratio with the aggregate average of the RF, VL, and VM, men demonstrated a trend toward higher hamstring activation ratio than women for the postcontact phase of the cut. This finding is consistent with others who report higher hamstring to quadriceps activation ratios for men, compared with women, during functional movements (17,20). The averaged hamstring to quadriceps timing ratio demonstrated that women achieved earlier activation of the hamstring in the precontact phase of the cut. No other significant differences in this measure were found for postcontact condition of the cut or for the pre- and postcontact condition of the jump.

The gender difference in jumping ability of the women in this study (75.20/0 of the value of men) compares similarly to previous research demonstrating that women have a vertical jump of 73.1% of their male counterparts (1). Thus, this measure of training status suggests that the female subjects in this study were not atypical.

## Practical Applications

Although the collective research in this area remains equivocal, results of the present study provide evidence that compared with women, men are hamstring dominant, particularly during the postcontact phase of the functional movements assessed in this study. Strength and conditioning interventions, such as resistance training and plyometrics may offer the potential for increased rate and magnitude of hamstring muscle recruitment and should be evaluated using EMG during movements that are similar to those that cause ACL injuries to determine if gender differences in hamstring muscle function can be reduced.

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